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Can organic farming help to reduce N-losses?

Experiences from Denmark

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Key words: dairy farming, efficiency, nitrogen, organic, pig farming, surplus

Abstract

This study is in two parts. In the first part, nitrogen (N) losses per unit of milk and meat in Danish conventional and organic pig and dairy farming were compared on the basis of farm data. In the second part, organic and conventional dairy farming were compared in detail, using modelling. N-surpluses at different livestock densities, fodder intensities, and soil types were simulated. Finally, simulated N-surpluses were used in national scenarios for conversion to organic dairy farming in Denmark. In Part one, pig farming was found to have a higher N-efficiency than dairy farming. Organic pig production had a lower N-efficiency and a higher N-surplus per kg meat than conventional pig production. The possibilities to reduce N-loss by conversion to organic pig production therefore appear to be poor. Organic dairy farming had a higher N-efficiency and a lower N-surplus per kg milk than conventional dairy farming. Conversion from conventional to organic dairy farming may therefore reduce N-losses. In Part two, a positive correlation between livestock density and N-surplus ha^{-1} was found for dairy farming. For all simulated livestock densities, fodder feeding intensities and soil types, organic systems showed a lower N-surplus per unit of milk produced than conventional systems. National scenarios for dairy farming showed that the present Danish milk production could be achieved with a 24% lower total N-surplus if converted from intensive conventional farming to extensive organic farming. At the same time, N-surplus ha^{-1} and N-surplus (t milk)$^{-1}$ would be lowered by 50% and 25% respectively. Changing from intensive to extensive conventional dairy farming with a livestock density equal to that in the organic scenario resulted in a reduction in N-surplus ha^{-1} of 15%. It was concluded that a reduction in total N-loss from agriculture is possible by converting from conventional to organic dairy farming but at the cost of either lower production on the present dairy farm area, or the current production on a substantially larger area.

Abbreviations: N-eff – nitrogen efficiency; LSU – Livestock Units; SFU – Scandinavian Feed Units

Introduction

Loss of nitrogen (N) caused by human activities leads to environmental problems locally, nationally and globally. The largest contribution to the human N-cycle comes from agriculture (Bleken and Bakken, 1997), so that a reduction in N-losses from agriculture will significantly lower the total N-loss to the biosphere.

Conversion from conventional to organic farming has been discussed as a possible way to reduce N-dissipation. In Denmark, dairy farming in particular has shown promising results. Some of the arguments in favour are that organic farming generally has lower N-inputs (e.g. no use of mineral fertilisers), lower livestock density and therefore lower potential N-losses. Arguments against organic farming are that technological advances such as use of pesticides, fertilisers and genetically modified organisms are not allowed, thereby limiting potential production per unit area. This study is in two parts and is a system-oriented approach where data from the farm level is used for the comparison (Conway, 1987; Dalgaard, 1997a). In the first part, N-losses per unit of production in Danish conventional and organic pig and dairy farming are compared on the basis of farm data. In the second part,

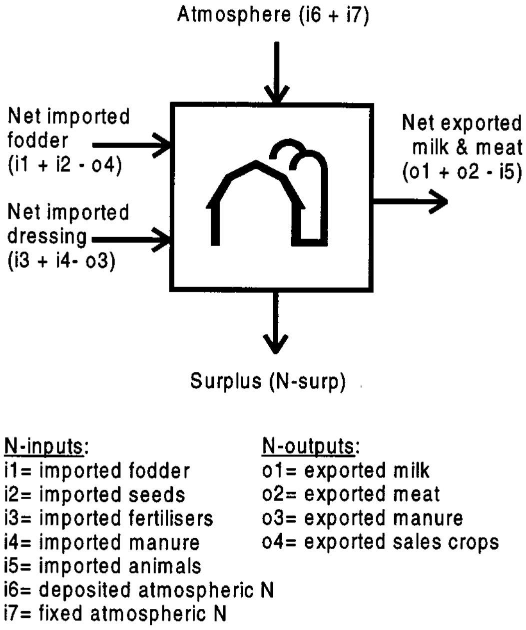

Figure 1. Farm N-inputs (i1-i7), N-outputs (o1-o4) and N-surplus i.e. in kg N ha^{-1} yr^{-1}.

organic and conventional dairy farming are compared in detail. Using modelling, N-surpluses at different livestock densities, fodder intensities, and soil types are simulated. Finally, simulated N-surpluses are used in national scenarios for con- version to organic dairy farming in Denmark and the scenarios are discussed in a national context.

Methods, data sources and models

N-surplus and N-efficiency

In this study, nitrogen surplus (N-surplus) and nitrogen efficiency (N-eff) were used as indicators of potential loss of nitrogen. N-surplus is defined as the difference between net N-output from the farm in form of milk and meat and the net N-input to the farm in form of net fodder import, net dressing import and N from the atmosphere. N-eff is defined as net exported milk and meat divided with net imported fodder, net imported dressing and N from the atmosphere (Figure 1, Equation (1) and (2)).

$$\text{N-surplus} = i1 + i2 + i3 + i4 + i5 + i6 + i7 - o1 - o2 - o3 - o4 \qquad (1)$$

$$\text{N-eff} = (o1 + o2 - i5)/[(i1 + i2 - o4) + (i3 + i4 - o3) + (i6 + i7)] \qquad (2)$$

Standards for N-content derived by Strudsholm et al. (1997) were used for calculations of N in i1, i2, o1 and o4. Where possible, analytical data were used in the calculation of N in i4 and o3, otherwise standard values from the Ministry of Agriculture and Fisheries (1996) were used. An N-content for live animals of 27 g N kg^{-1} was used for the calculation of i5 and o2. Deposited N from the atmosphere, i6 ,was set to 21 kg Nha^{-1}year^{-1} (Bendixen et al., 1997; Grundahl and Hansen, 1990). For clover (*Trifolium spp.*), biologically fixed N, i7, was estimated via % clover plants, with the model presented by Kristensen et al. (1995). For other *Leguminosae,* fixed N was estimated from harvested N according to Kristensen and Kristensen (1992).

Farm data

The Danish Institute of Agricultural Sciences has collected data from pilot farms for many years. Data collection was initiated by the Marshall plan after the Second World War and, since 1987, comprehensive data on internal and external mass flows have been collected from both organic and conventional dairy farms. In recent years, data collection from pig, plant and poultry farms has also been initiated. Data are published in annual reports (e.g. Kristensen, 1997).

The dairy-farm data set used for analysing N-turnover in this study was collected from 14 organic and 16 conventional pilot farms over a two-year period, with biweekly registrations on each farm (Halberg et al., 1995). Data from a typical conventional pig farm were collected by Halberg (1996). Grown crops, average livestock density, average crop- and milk yields for the analysed farms corresponds to the average for organic and conventional dairy and pig farms in Denmark (Danmarks Statistik, 1996). For organic pig farming, budgeted figures from prototype pig farming systems described in Kristensen and Kristensen (1997) were used, since very few organic pig farms are established in Denmark, and no data from pilot organic pig farms are available.

Table 1 shows average production intensities for the farming systems. Animal production intensity was measured in LSU ha^{-1}, where 1 LSU (Livestock Unit) corresponds to one 550 kg dairy cow, 3 sows or 30 porkers produced per year. Production intensity was also expressed in kg milk ha^{-1} yr^{-1} and kg meat ha^{-1}

Table 1. Average production intensities on farming systems where N-turnover is compared

		Dairy farms		Pig farms	
		Conventional	Organic	Conventional	Organic
Livestock	LSU ha^{-1}	1,5	1,1	2,3	0,7
Milk	kg ha^{-1} yr^{-1}	8200	5600	0	0
Animals sold	kg ha^{-1} yr^{-1}	330	230	4900	1200
Crop yield	SFU ha^{-1} yr^{-1}	6100	4600	4400[a]	3200[a]

[a] Inclusive fallow area.

yr^{-1} and in SFU ha^{-1} yr^{-1}, where 1 SFU (Scandinavian Feed Unit) equals the fodder value in 1 kg barley or 12.5 MJ metabolisable energy (ME). The crop yields were on average higher on dairy farms than on pig farms. This was due to a higher percentage of roughage crops, which give a higher yield in SFU ha^{-1} yr^{-1} than grain crops (Halberg and Kristensen, 1997).

Dairy farm models

Models for mass-flows on organic and conventional dairy farms (Dalgaard et al., 1997) were used to investigate N-surplus on single farms and to model national scenarios for N-loss from dairy farming. The advantage with models, compared with pilot farm figures, were that single factors could be varied, and their specific influence on N-turnover could be investigated. In this study, models were used to investigate consequences for N-surplus when livestock density, feeding intensity and soil type were varied in organic and conventional dairy farming systems.

Model farm types were set up for the purpose of comparing organic and conventional dairy farming. The cows in organic and conventional production systems were presumed to have identical milk yield potentials and identical health status. N-turnover was modelled for three fodder intensities (extensive, average and intensive), each with a corresponding milk yield per cow per year (Table 2).

Milk yields were modelled from the corresponding fodder plan (Dalgaard et al., 1997, Table 2) with the model SIMHERD (Sørensen et al., 1992). Crop yields were estimated with Halberg and Kristensen's (1997) model for crop yields on dairy farms in Denmark. According to this model, yields were significantly influenced by system (organic, conventional), soil type (loamy, sandy and irrigated soil) and crop type. The modelled farm crops were fertilised according to Danish practice where the modelled conventional farms were presumed to import mineral fertiliser so that

Table 2. Characteristics for fodder plans on modelled dairy farms (after Dalgaard et al., 1997)

		Fodder feeding intensity		
		Extensive	Average	Intensive
Milk yield	kg cow^{-1} yr^{-1}	6300	8000	8700
Conventional plan:				
Concentrates purchased[a]	SFU cow^{-1} yr^{-1}	949	1533	2044
Grain[a]	SFU cow^{-1} yr^{-1}	584	1278	1278
Grassed grass/clover[a]	SFU cow^{-1} yr^{-1}	1606	1387	1278
Other roughage [a]	SFU cow^{-1} yr^{-1}	1278	1205	1789
Total fodder [a]	SFU cow^{-1} yr^{-1}	4417	5403	6389
Total crude protein	kg cow^{-1} yr^{-1}	907	1081	1243
Organic plan:				
Concentrates purchased [a]	SFU cow^{-1} yr^{-1}	657	1205	1898
Grain [a]	SFU cow^{-1} yr^{-1}	694	1460	1460
Grassed grass/clover [a]	SFU cow^{-1} yr^{-1}	1789	1606	1387
Other roughage [a]	SFU cow^{-1} yr^{-1}	1279	1133	1643
Total fodder [a]	SFU cow^{-1} yr^{-1}	4419	5404	6388
Crude protein	kg cow^{-1} yr^{-1}	949	1146	1335

[a] 1 SFU (barley equivalent)= 12.5 MJ ME.

Danish norms for N-fertilisation were attained (Ministry of Agriculture and Fisheries, 1996). For instance the norm for barley on clayey soil and West Danish climate is 124 kg plant available N ha^{-1} after cereals and 94 kg ha^{-1} after grass/clover. Modelled organic farms were presumed not to import or export manure. Only N contended in the straw was accounted for in ammonia treated straw for fodder. Average% coverage of N-fixing plants in clover-grass was set to the average number measured on Danish pilot farm fields (22% on conventional and 44% on organic dairy farms) (Kristensen and Halberg, 1995).

National scenarios for dairy farming

National scenarios were set up for N-surplus from three different combinations of organic and conventional dairy farming, while maintaining the present Danish milk production. The aim of the scenarios was to quantify the national reduction in N-loss when converting from conventional to organic dairy farming, and to show constraints for milk production and land use, when reducing the total N-loss from agriculture by conversion to organic dairy farming.

The scenarios were generated using data from the modelled dairy farms, with average feeding intensity (Table 2), distributed on loamy, irrigated- and non-irrigated sandy soils. To adjust for the fact that most Danish dairy farms are located on sandy soils in the west (Dalgaard, 1997a), the dairy farm areas were distributed on soil type areas in Denmark (Larsen and Sørensen, 1996) according to the number of cows in Danish counties (Danmarks Statistik, 1996). All soils with more than $10\%_{(\mathrm{w})}$ clay (<2 μm) or more than $10\%_{(w)}$ organic matter were classified as loamy (less than 0.5% of Danish soils are clay or silt soils). Only sandy soils were assumed to be irrigated, and the area of irrigated soil on dairy farms in Danish counties was set according to Danmarks Statistik (1989).

Scenario 0 shows an intensive case, resembling the present situation in Denmark with 98% conventional and 2% organic milk production, and a livestock density (1.7 LSU ha^{-1}) near the limits of the EU Nitrate-Directive (Danmarks Statistik, 1996, Alders 1991). Scenario 1 shows conventional farming converted to a livestock density similar to the average in organic dairy farming (1.1 LSU ha^{-1}). The extra area, not needed for roughage and grain fodder production, is used for production of grain cereals for sale. Scenario 2 shows a 100% conversion to organic farming with an average livestock density of 1.1 LSU ha^{-1}. The results of the scenarios are shown in Tables 6 and 7.

Results

Comparison of dairy and pig farming

The method for examining farm N-turnover illustrated in Figure 1 was applied to the described farm data (Table 1). The results are shown in Figure 2.

The investigated conventional dairy and pig farms had larger inputs of N in imported fodder and fertilisers per ha and a larger N-surplus than the organic farms. Dairy farming on average had a larger N-fixation and a larger N-surplus in kg N ha^{-1} than pig farming. The most important source of N-input to conventional dairy farming was fertiliser import, while to organic dairy farming it was N fixed and deposited from the atmosphere. Conventional pig farming was dependent on a large fodder and fertiliser import but also had a large export of meat and manure. The import of fodder and manure in organic pig farming was relatively small per ha, but so was the meat production and N-surplus. Table 3 gives key figures for N-turnover in the compared systems.

The modelled organic pig production had a higher N-surplus per kg meat and a lower N-efficiency than conventional pig production even if the N exported in manure was not included (Table 3). Therefore, the lower N-surplus per ha in the organic model farm is most likely caused by the lower stocking rate. It thus seems that a reduction in N-surplus per ha in pig production would be easier obtained by reducing livestock density in conventional pig production than converting to organic pig production. The organic dairy farming had a lower N-surplus per kg milk and a higher N-efficiency than conventional dairy farming. Conversion from conventional to organic dairy farming may therefore result in a lower N-dissipation. This was examined further using modelled dairy farms.

Livestock density and modelled N-surplus on dairy farms

The lower N-surplus on the organic dairy farms than on the conventional dairy farms was confounded by differences in production intensity (Table 1). To unravel these interelationships N-surplus (kg ha^{-1}yr^{-1}) was plotted in relation to livestock density (LSU ha^{-1}) for pilot and modelled dairy farms (Figure 3).

Halberg et al. (1995) found that the effect of livestock density on N-surplus per ha was significant (P <0.0001). There was interaction between livestock density and system (P <0.08, i.e. not quite significant at the 5% level). For conventional farms, the linear regression coefficient was 117 kg N-surplus ha^{-1} LSU^{-1} and for organic farms, 33 kg N-surplus ha^{-1} LSU^{-1}. Because of the effect of livestock density, comparison of N-surplus from conventional and organic dairy farming should be made for the same livestock density and therefore the national level scenarios for N-surplus includes a scenario with only 1.1 LSU ha^{-1} conventional dairy farming (Table 6).

Calculated N-surplus from both organic and conventional modelled dairy farms fitted well into the scatter of N-surplus from the pilot farms (Figure 3). The modelled farms on loamy and irrigated sandy soils had the highest livestock density and the highest N-surplus ha^{-1}. This was due to the definition

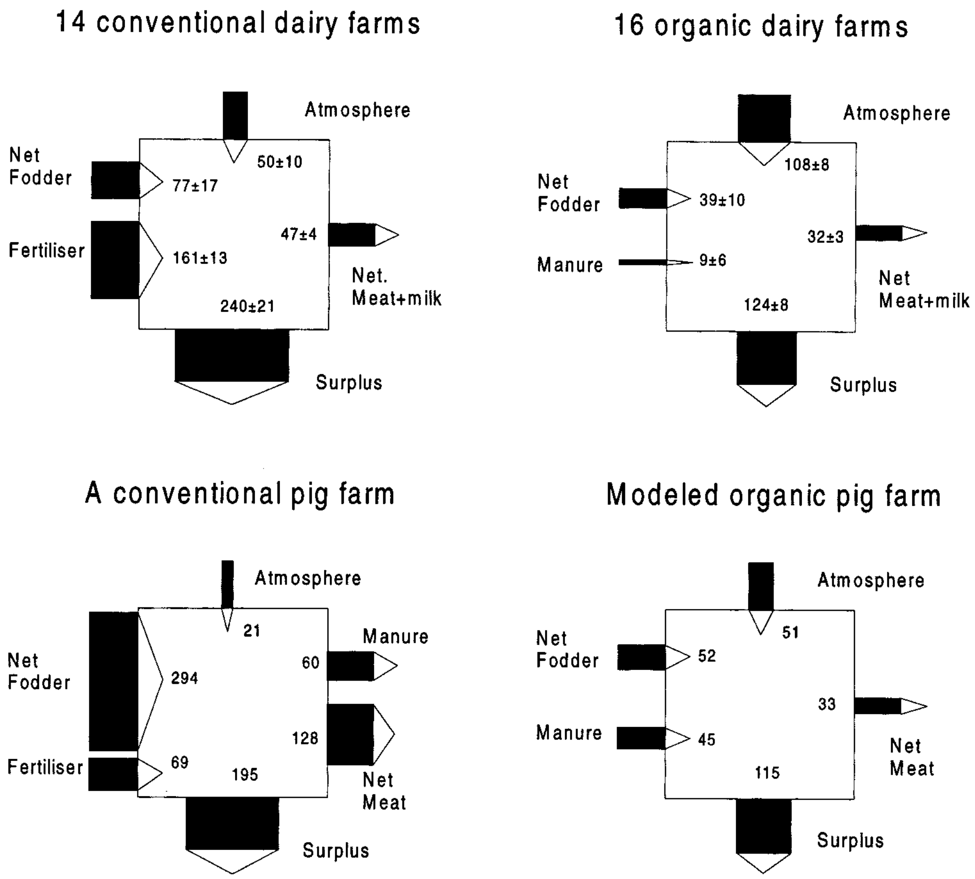

Figure 2. Farm N-turnover (kg N ha^{-1} yr^{-1}) in Danish conventional and organic farming. Statistical data from pilot dairy farms ± 95% confidence intervals (Halberg et al., 1995), and results from a typical conventional pig farm (modified from Halberg 1996) and from a modelled organic pig farm (Kristensen and Kristensen 1997).

Table 3. Average N-surplus per unit of area or production and N-eff for the farming systems (Figure 2)

		Dairy farms		Pig farms	
		Conventional	Organic	Conventional	Organic
N-surplus	kg ha^{-1} yr^{-1}	240	124	195 (255^{b})	115
N-surplus	kg LSU^{-1} yr^{-1}	160	112	85 (111^{b})	164
N-surplus^{a}	kg (t milk)$^{-1}$	29	22	-	-
N-surplus	kg (t meat)$^{-1}$	-	-	39 (52^{b})	96
N-eff	%	16	21	40 (33^{b})	22

^{a}Meat converted to milk according to N-content.
^{b}Calculated as in Equation (1) and (2) but without deducting the exported manure-N (o3) since it might not be considered a real product.

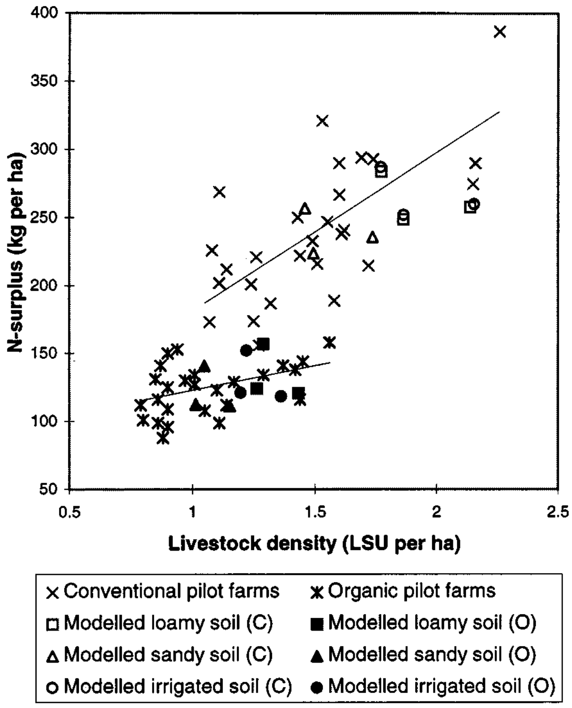

Figure 3. N-surplus (kg ha^{-1} yr^{-1}) versus livestock density in (LSU ha^{-1}). Organic and conventional pilot dairy farms analysed in Halberg et al. (1995) are compared with modelled organic (O) and conventional (C) dairy farms on loamy, non-irrigated sandy and irrigated sandy soil, each with the three different fodder intensities shown in Table 2. Linear regression lines are calculated from pilot farm data.

of the modelled farm area as the area needed to produce the roughage and grain to feed cows producing a fixed amount of milk (Dalgaard et al., 1997). As the yields on loamy soils were higher than on non-irrigated sandy soils, 1 ha loamy soil could feed more cows, and livestock density increased (Table 4).

Fodder feeding intensity and modelled N-surplus on dairy farms

To investigate the influence of fodder feeding intensity on N-loss per unit of production, N-eff and kg N-surplus (t milk)$^{-1}$ were compared for the three fodder intensities on modelled organic and conventional dairy farms on irrigated sandy soil (Table 5).

Both systems showed the highest N-eff and the lowest kg N-surplus (t milk)$^{-1}$ for the average fodder feeding intensity. However, when the fodder feeding intensity was raised, the differences between organic and conventional dairy farming, indicated with N-eff and N-surplus, decreased (Table 5). This was, as explained below, caused by intrinsic differences between the two systems: when fodder feeding intensity and kg crude protein in the fodder is raised, kg N in manure rises. Consequently, the import of mineral fertiliser on conventional model dairy farms could be reduced without decreasing the crop yield. In contrast, when fodder feeding intensity is raised on organic dairy farms, the increased external import of N via fodder in an intensive fodder plan could not be counteracted by a lower import of fertilisers as in conventional systems. Therefore, the relative difference in kg N-surplus per t milk between organic and conventional dairy farming decreased with increasing fodder feeding intensity. On the other hand, for both organic and conventional dairy farming systems the number of cows needed to produce a fixed amount of milk decreases when fodder feeding intensity is raised. This decreases the fodder

Table 4. Modelled farm area required for self-sufficiency in roughage and grain for the modelled conventional and organic dairy farms producing 500 t milk yr^{-1} on loamy, irrigated sandy and non-irrigated sandy soils with low, average and high fodder intensities (after Dalgaard et al., 1997)

Fodder feeding intensity		Extensive	Average	Intensive
Conventional				
Loamy soil	ha	51	46	44
Irrigated sandy soil	ha	51	46	44
Non-irrigated Sandy soil	ha	63	57	54
Loamy soil	ha	76	68	61
Organic				
Irrigated sandy soil	ha	80	72	64
Non-irrigated Sandy soil	ha	94	85	75

Table 5. N-eff (%) and N-surplus (kg per t milk) at three fodder feeding intensities for modelled organic and conventional dairy farms on irrigated sandy soil (after Dalgaard et al., 1997)

Fodder feeding intensity		Extensive	Average	Intensive
N-eff				
	Organic	27	28	25
%	Conventional	18	20	19
	Difference	9	8	6
N-surplus				
	Organic	19	17	20
kg (t milk)$^{-1}$	Conventional	26	23	25
	Difference	7	6	5

energy needed for maintenance of the cows (i.e. fodder energy that does not go to milk production), and the need for fodder import decreases in proportion. The described relative increase of N in manure and the relative decrease of needed N in fodder for maintenance of the cows counteract one another and causes that kg N-surplus per t milk as shown will have a minimum at the average fodder feeding intensity.

National scenarios for N-surplus from dairy farming

National scenarios were set up for N-surplus from three different combinations of organic and conventional dairy farming, while sustaining the present Danish milk production (Table 6). Key figures for N-surplus and production constraints for the three scenarios are shown in Table 7.

To facilitate the comparison of conventional and organic production systems scenario 1 illustrates the expected effect on N-surplus if livestock density in conventional farming is reduced to 1.1 LSU ha^{-1}, which is the same as in the organic scenario (2). The dairy farm area in scenario (1) and (2) differ from the dairy farm area in scenario (0), when comparing total N-surpluses.

Discussion

The presented results on N-turnover in organic and conventional dairy and pig farming provide a basis for discussion of how organic agriculture may help to reduce N-losses per unit of production. This discussion is relevant (Stopes, 1995) because, although organic agriculture showed the lowest N-surplus per area, at the same time productive capacity in organic farming was lower than in conventional farming, and a larger area was needed to produce the same amount of feed. It is therefore a discussion of the dilemma between high production and low environmental impact.

N-surplus and N-eff as indicators for N-loss

N-surplus, defined in Figure 1, was used as an indicator of potential N-loss from the farming system. N-surplus covers a number of N-losses in the form of dissolved N (mainly nitrate), gaseous N (ammonia, di-nitrogen, nitrogen oxides, etc.) and solid N (mainly organic matter). Some of the surpluses may temporarily accumulate as biomass or as humus in the soil (Magid and Kølster, 1995), but as the system reaches steady state, N-surplus and N-loss will converge (Ekeberg and Riley, 1995). N-surplus describes the absolute (kg N) part of the potential N-loss from the farming system while N-eff describes the relative (%) potential N-loss. A high N-eff is therefore not necessarily an indicator of a low absolute N-loss from the system. The farms that had an N-surplus of 300 kg N ha^{-1}yr^{-1} in Figure 3, therefore did not necessarily have a lower N-eff than farms with an N-surplus of 150 kg N ha^{-1} yr^{-1}. It is important to understand this difference between surplus and efficiency, when using N-surplus and N-eff as indicators for environmental impact. For example, critical loads of N from agricultural systems to recipients are absolute figures and can only be indicated by N-surplus, as N-eff cannot determine whether the critical load is exceeded or not.

The lower N-surplus (kg per t meat) in conventional than in organic pig farming could be explained by different production methods. In the former, chemically produced amino acids and growth promoters like copper and zinc (Larsen et al., 1996) were added to the feed, and antibiotic medicine could be used more freely. Furthermore, wheat grain, which is a major part of pigs’ feed, may be grown more N-efficiently in optimised conventional cropping systems, where pesticides and fertilisers are used (de Wit, 1992). The lower N-surplus (kg per t milk) in organic dairy farming than in conventional dairy farming may be explained by differences in fertilising strategy. Conventional modelled dairy farms used mineral fertilisers to optimise crop yields. In contrast organic farms did not have this opportunity, so the organic crops had to use N from the soil and from organic manure more efficiently, resulting in a low N-surplus per unit of production (Halberg and Jensen, 1996). The effect of the difference between conventional and organic fertilising strategy may be especially high on dairy farms with many roughage crops like grass/clover and fodder beets. These crops have a long growing season, so N mineralised from organic matter in the soil could be used efficiently. This idea is supported by a reported lower relative decrease in fodder beet and grass/clover crop yields when converting from conventional to organic agriculture (Halberg and Kristensen, 1997).

Differences between fodder plans in organic and conventional dairy farming did at the same fodder feeding intensity not affect milk yields in dairy production (Dalgaard et al., 1997) but if growth hormones were legalised for use in Danish conventional dairy farming but not in organic dairy farming, fodder could be used more efficiently in the former system,

Table 6. Calculated scenarios for dairy farm production in Denmark (excluding fattening of bulls). Modelled for average feeding intensity

		Soil type			
		Sandy non-irrigated	Sandy irrigated	Loamy non-irrigated	Total or average
Intensive case (0)					
Fodder crops[a]	10^3 ha	218	96	166	480
Sales crops	10^3 ha	0	0	0	0
Milk	t ha^{-1} yr^{-1}	8.6	10.7	10.7	9.8
N-surplus	kg ha^{-1}	220	248	244	234
Livestock	LSU ha^{-1}	1.5	1.8	1.8	1.7
Conventional (1)					
Fodder crops[a]	10^3 ha	216	95	164	475
Sales crops	10^3 ha	71	63	108	242
Milk	t ha^{-1} yr^{-1}	6.5	6.5	6.6	6.5
N-surplus	kg ha^{-1}	197	207	197	199
Livestock	LSU ha^{-1}	1.1	1.1	1.1	1.1
Organic (2)					
Fodder crops[a]	10^3 ha	318	148	242	707
Sales crops	10^3 ha	0	0	0	0
Milk	t ha^{-1} yr^{-1}	5.9	7.0	7.4	6.6
N-surplus	kg ha^{-1}	113	121	124	118
Livestock	LSU ha^{-1}	1.0	1.2	1.3	1.1

[a] Roughage and grain for fodder.

with a resulting decreased N-surplus in kg per t milk produced (Tucker et al., 1995).

Organic dairy farms had a lower N-surplus per area than conventional ones. This corresponds well with the results of Van der Werff et al. (1995). He studied organic farms in The Netherlands and calculated with a slightly different method than in this study an N-surplus of 83 kg ha^{-1} compared with an N-surplus of 391 kg ha^{-1} for intensive conventional dairy farms. N-surplus from intensive dairy farms in The Netherlands varied between 32 and 44 kg N-surplus (t milk)$^{-1}$ according to Korevaar (1992). However, Korevaar's results were found with different methods for calculating i6 and i7 (Figure 1) and were for dairy farms with a higher livestock density and a correspondingly higher N-surplus of 376 to 650 kg ha^{-1}. Also N-eff can vary considerably, as Halberg (1996) reports a variation of between 20% and 47% on conventional pig farms. Other authors have calculated N-efficiencies as output/input (o/i) ratios. According to Aarts et al. (1992), intensive conventional dairy farms in The Netherlands had an o/i-ratio varying from 13% on clayey soils to 15% on sandy soils. Correspondingly, van der Werff et al. (1995) calculated that the average% of total input in output products on intensive conventional dairy farms was 12% compared with 31% on organic dairy farms. Jarvis (1993) reports an o/i-ratio for intensive dairy farming in England of 20%. A similar correspondence between low production intensity systems and low kg N-surplus ha^{-1} was confirmed by Wagstaff (1987) and by Langeveld and Overbosch (1996), who found a low N-surplus of 114 kg ha^{-1} on extensive conventional dairy farms in Poland. This finding is discussed further, below.

Livestock density, feeding intensity and N-surplus in dairy farming

Both modelled figures and results from registrations on organic and conventional dairy farms showed a significantly higher N-surplus ha^{-1} when the LSU ha^{-1} was raised (Figure 3). Doluschitz et al. (1992) analysed N-surplus ha^{-1} on dairy farms in Baden-Württemberg, Germany, and found a similar, linear correlation in the range from 1.3 to 3.9 LSU ha^{-1}. However, subsequent single-farm analysis showed that management of the individual farm was an important

Table 7. Scenarios for area (ha), production (kg milk and grain) and N-surplus (kg ha^{-1} yr^{-1}, kg (t milk)$^{-1}$ and 10^6 kg yr^{-1}) from dairy farming maintaining the present Danish milk production of 4700 x 10^6 kg milk yr^{-1}

		Intensive case (0) 1.7 LSU ha^{-1}	Conventional (1) 1.1 LSU ha^{-1}	Organic (2) 1.1 LSU ha^{-1}
Milk production	10^6 kg yr^{-1}	4700	4700	4700
Grain production	10^6 kg yr^{-1}	0	1600	0
Dairy farm area	10^3 ha	480	717	707
Average N-surplus	kg ha^{-1} yr^{-1}	234	199	118
Average N-surplus	kg (t milk)$^{-1}$	24	24	18
Total N-surplus	10^6 kg yr^{-1}	110	140	84

parameter for low N-surplus as well, and LSU ha^{-1} could not be used as the only parameter to explain N-surplus per area. The use of modelled dairy farms in the current study made it possible to vary single factors such as feeding intensity within systems. In conventional dairy farming, N-surplus per unit of milk produced decreased when fodder feeding intensity was raised from extensive to average or intensive. A similar tendency was found by van Keulen et al. (1996) and Korevaar (1992), according to whom N-surplus decreased in average from 43 to 32 kg (t milk)$^{-1}$ when milk yield increased from 5.6 to 6.9 t^{-1}cow^{-1-}yr^{-1}. However, the absolute figures could not be compared, because this study was the only one where N-surplus was changed solely by means of changed fodder feeding intensity in the models, and because the farms referred to by Korevaar (1992) were characterised by a higher livestock density than is legally possible in Denmark (Ministry of Agriculture and Fisheries, 1996). Differences in self-sufficiency with fodder (Table 2) must be considered when N-losses from organic and conventional farming systems are compared, as N-losses in the farming areas where any imported fodder is produced, are not accounted for in the farm N-balance (Figure 1). However, N lost in external areas, where the imported fodder is produced, do not affect the local N-loss, and is mainly interesting when comparing N-losses from, e.g. two countries with different fodder imports per unit of production.

Can organic agriculture help to reduce N-losses ?

Conventional pig production had lower N-surplus (kg per t meat) than organic pig production, and further development of organic pig-farming systems is therefore needed, if they are to contribute to lower N-losses per unit of production. In contrast, organic dairy farming had lower N-surplus (kg per tmilk) than conventional dairy farming and national scenarios for conversion from conventional to organic dairy farming were therefore set up.

Scenarios for conversion from conventional to organic dairy farming in Denmark showed promising results for reduced N-loss, but also disadvantages. If conventional dairy farming with 1.7 LSU ha^{-1} is converted to organic dairy farming with 1.1 LSU ha^{-1}, average N-surplus per t milk and average N-surplus per ha in Denmark could be reduced by 25% and 50%, respectively, and total N-surplus from dairy farming could be lowered from 110$\times$10^6 to 840$\times$10^6 kg N year^{-1}. This figure should be compared with the total N-surplus from agriculture in Denmark, reckoned by Kyllingsbæk (1995) to be 469$\times$10^6 kg N year^{-1}, or 180 kg N ha^{-1}yr^{-1}. Consequently the calculated N-surplus from dairy farming, excluding the fattening of bulls, of 110$\times$10^6 kg N year^{-1} accounts for a considerable part of the total N-surplus, and conversion to organic dairy farming would reduce total N-surplus from dairy farming in Denmark by around one fourth, if dairy farm N-import to the country is maintained at the present level.

The reduction of N-surplus when converting to organic dairy farming resulted in a 47% extension of the total dairy farm area, which implied a decreased area available for other farm types, i.e. conventional pig and plant producing farms. It so happens that the areas of Denmark where most dairy farms are situated also have many pig farms, and according to the EU Nitrate-directive (Alders, 1991), extra animals are not allowed on the present area in these regions (Dalgaard, 1997b). Therefore, increased organic dairy farming in these areas would imply a decrease in pig production. That might imply economic loss. An assessment of the cost-effectiveness of reducing N-pollution demands integrated economic and ecological analysis, as discussed by Vatn et al. (1996), but is beyond the scope of this study.

An alternative to the organic dairy farming scenario (2) was changing to conventional dairy farming with lower livestock density (scenario 1). This reduced N-surplus per area by 15%, while the total N-loss from dairy farming was increased with 27%. However, land was freed for grain production for export, and the economic cost of scenario 1 may therefore be lower than the cost of converting to organic dairy farming with an equal livestock density (scenario 2). At present, organic dairy farming in Denmark is dependent on imports of concentrates and manure from conventional farms or organic farms abroad. A conversion of all branches, like dairy-, pig- and plant production, to organic agriculture might therefore lead to problems with fodder and nutrient supply to Danish agriculture, which could either be solved by increased import of fodder stuffs and nutrients to Denmark or a considerable decrease in the production intensity and thereby a considerable reduction in the net agricultural production. This will be investigated further in a new research project (Michelsen, 1996).

The conclusion of the investigation is that a reduction in total N-loss from agriculture is possible by converting from conventional to organic dairy farming. On the contrary, conversion from conventional to organic pig production with the present production methods will increase total N-loss. If N-loss is reduced by conversion to 100% organic dairy farming, and the present milk production is sustained, 47% extra dairy farm area is needed, and the remaining net agricultural production must be reduced.

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